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TIME SMEAR AND FREQUENCY SMEAR STUDIES OF THE BIFI RANGE.(U)
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(6) # TIME SMEAR AND FREQUENCY SMEAR STUDIES ON THE BIFI RANGE[1]

(1)

by

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ABSTRACT[2] (12) 13p.

The BIFI range is a shallow water acoustic range in Long Island Sound, about 19 miles long and 120 feet deep. Results of time smear and frequency smear studies made on this range are presented. It is shown how these results may be used to predict signal fluctuation. In time smear studies, the received signal is divided into a front, main arrival and tail. The relative energies of the three sections of the signal are computed and these results are used to predict the range of signal fluctuations. The above analysis and computation are easily carried out on a digital computer using as input data automatically punched on IBM cards. Frequency smear is the doppler shift undergone by a signal as a result of being reflected from a moving surface. Many frequency smear spectra were obtained for varying sea states, and from these, dispersion as a function of sea state was calculated. The dispersion increased with sea state, in agreement with theory.

(16) F11552 (17) SF11552001

[1]This memorandum consists of the abstract, text and slides of a paper presented by the authors at the Seventy-Eighth Meeting of the Acoustical Society of America in San Diego, California, on 6 November 1969.

[2]This abstract was previously published in The Program of the Seventy-Eighth Meeting of the Acoustical Society of America, San Diego, California, 4-7 November 1969.

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INTRODUCTION

The Navy Underwater Sound Laboratory is engaged in shallow water investigations for the purpose of formulating an accurate model, suitable for sonar performance prediction in this medium. A paper read at a previous meeting of the Society described measurements of propagation loss and dispersion analysis when a wide band source was used. The present paper will describe how time smear and frequency smear data may be related to signal fluctuation in shallow water.

The tests discussed here were conducted on the BIFI range shown in Figure 1. The range has a length of approximately 19 nautical miles and has a depth of about 120 feet through most of its extent. At Block Island, three projectors with operating frequencies of 127, 400 and 1700 hertz are bottom mounted at a 55-foot depth at point S. Several hydrophones are bottom mounted near Fishers Island. The one currently being used is located in 155 feet of water at point H. The Block Island and Fishers Island field stations are connected by means of data transmission lines to the Data Acquisition and Reduction Center at the Laboratory which is located about 7 miles northwest of Fishers Island. All tests discussed in this paper were conducted at a frequency of 1700 hertz.

TIME SMEAR

The first parameter to be duscussed is time smear, and Figure 2 will help clarify some terms to be used. The outgoing pulse is assumed to be rectangular, of duration T_o. The received signal is divided into three sections: the front, the received pulse, and the tail. A possible signal with all three parts is shown in the figure. To locate precisely the four points which determine the limits of these three parts of the signal, we first find E_{amb}, the energy contained in an interval of ambient noise of duration T_o. The equations for this is shown at the left in the figure.

We multiply this value by a constant k which serves the purpose of establishing a threshold for the signal. The received pulse, B to C on this figure is that section of the received signal, of duration T_o, for which the energy is a maximum, as indicated by the expression below this section. The existence and duration of the front are then determined by applying, in order, the criteria shown below section AB of the figure. Starting from the left, the incoming signal is checked to find the first section of duration T_o for which the energy is greater than kE_{amb}, as shown in the first inequality below section AB. The first point in this section for which the inequality for p_A^2 is satisfied is then found. Finally, a check for the last inequality is made. The first point for which all three conditions are satisfied is point A, and section AB is the "front" of the signal. The last part of the signal is treated in a similar manner to determine point D and the duration of the "tail".

Of course, for this method of selection to be at all feasible, it must be automated. In our case this has been done by digitizing the data by means of an A to D converter, and having a digital computer do all the checking and selection described above, as well as the calculations described below.

Having found the limits of the signal, we compute the energy spread for any one transmission. Of interest for this purpose is the energy in the front, F(front), and tail, F(tail), respectively, expressed as a fraction of the energy in the received pulse. A plot of the values of F(tail) and the corresponding length of tail, in milliseconds, is shown in Figure 3.

Plots of this type may be used in studying the multipath structure of the medium. The data in Figure 3 were taken under calm sea conditions. As may be seen, the points cluster about a value of length of tail of about 1200 milliseconds. This, when added to the length of the main arrival, gives a signal length about three times the outgoing pulse length, thus showing that probably three paths are predominant. Similar data for rough seas showed a minimum of two paths. These conclusions are consistent with those reached in the basis of LFM sweep data and normal mode analysis.

From the slide we also see that the median value of F(tail) is .066. Thus, the median energy level in the tail is 11.8 db below that of the received pulse. As shown in Figure 4, this median level can cause a variation of 4.5 db in the received signal, depending on the phase relationship of the main and secondary arrivals.

The maximum value of F(tail) found in a series of runs was 0.21. This can cause a variation in amplitude of the received pulse of 8.6 db. To this must be added the variability noted in the energy content of the received pulse for different transmissions. The ratio of maximum to minimum values of energy for all transmissions was 10.2, and this can cause a variation of 10.1 db. The combined effect of these two parameters account for a possible signal variation of 19db. Similar calculations for data at a higher sea state, showed corresponding variations of 5.2 db, and 47 db, respectively.

Variations of these orders of magnitude were actually observed. In tests conducted in conjunction with a time smear test, the following data were obtained. For 10 pulses of 45 seconds duration each, taken at low sea state, 7 showed a variation of 9-15 db, with the other 3 showing variations of 18, 23 and 27 db, respectively. For high sea states, variations in excess of 40 db have been observed.

FREQUENCY SMEAR

Another parameter useful in the study of fluctuations in acoustic signals is frequency smear. This is the name given to the doppler shift undergone by an acoustic CW wave upon reflection from a surface which has a component of motion in the direction of propagation. Under ordinary conditions, the doppler shift is only a fraction of a hertz, and for this reason a very narrow band spectrum analyzer is required to measure frequency smear.

The procedure for obtaining frequency smear measurements on the BIFI range was as follows. A 1702 hertz pulse 100 seconds long was transmitted from the Block Island projector. It was received on the Fishers Island hydrophone and sent to the BIFI Laboratory at NUSL over the data line. The signal was then mixed with a locally generated 1700 hertz tone. The resultant signal was fed into a spectrum analyzer with an effective bandwidth of 0.01 hertz. A photograph of the dispersion curve thus obtained is shown in Figure 5.

Such curves were obtained twice daily over a long period of time as part of the BIFI propagation measurements, with intent to use them as a measure of signal variability. As a first step in this direction, the data on the photographs were digitized and transferred to IBM cards. The data were then used to compute the energy as a function of frequency, and from this, histograms were plotted. A total of 65 separate histograms, covering a variety of ambient conditions, was obtained.

The data were then grouped as a function of sea state, and ensemble averages were obtained and plotted as histograms. Figure 6 shows the results obtained for sea state 3. This is typical not only of the other ensemble averages, but also of individual transmissions. As a measure of the dispersion, the percentage of energy contained in the center 0.1 hertz band was used. The results are shown in Figure 7. As may be seen, the percentage energy in the center band decreases to about 2/3 at a wind speed of 15 knots, after which it stays roughly constant.

Theoretical values for the expected dispersion under conditions of these tests are not yet available. Roderick and Cron of NUSL have calculated the dispersion for a propagated sinusoidal acoustic wave reflected once from a moving surface composed of a number of discrete frequencies. In our experiments, ray tracing has shown that as many as 40 reflections take place between transmitter and receiver. The situation is further complicated by the interference suffered by the waves due to the several acoustic paths which exist in this shallow water channel, and by the irregularity and more or less random variation of the surface. The data provided here may serve as a basis for extending the theory of dispersion to more complicated cases than those treated thus far.

An opportunity to study energy dispersion under a wide variety of conditions was afforded by a 48-hour test conducted as part of the BIFI series. In this test transmission was maintained continuously for 48 hours, and frequency smear measurements were made every 30 minutes. Ambient conditions changed during the course of the tests, and the data were subdivided accordingly. The results are shown in Figure 8. The first three conditions show increasing dispersion for increasingly rough conditons. However, the last state in which the sea was calming down, shows greater dispersion than sea state 2. This is attributed to a time lag in cause and effect which has also been noted on other occasions both at NUSL and by other investigators. Further investigation of this time lag is planned.

SUMMARY

To summarize, it has been shown how time smear and frequency smear were used in the study of signal variability at NUSL. Time smear calculations were used to predict the maximum variability to be expected for two different sea states, and the predictions were found to agree with observed values. Conditions under which frequency smear measurement have been made are very complex, and have not yet been treated analytically. However, the dispersion does increase with increasing sea state, as would be expected on the basis of analysis of more simple cases.

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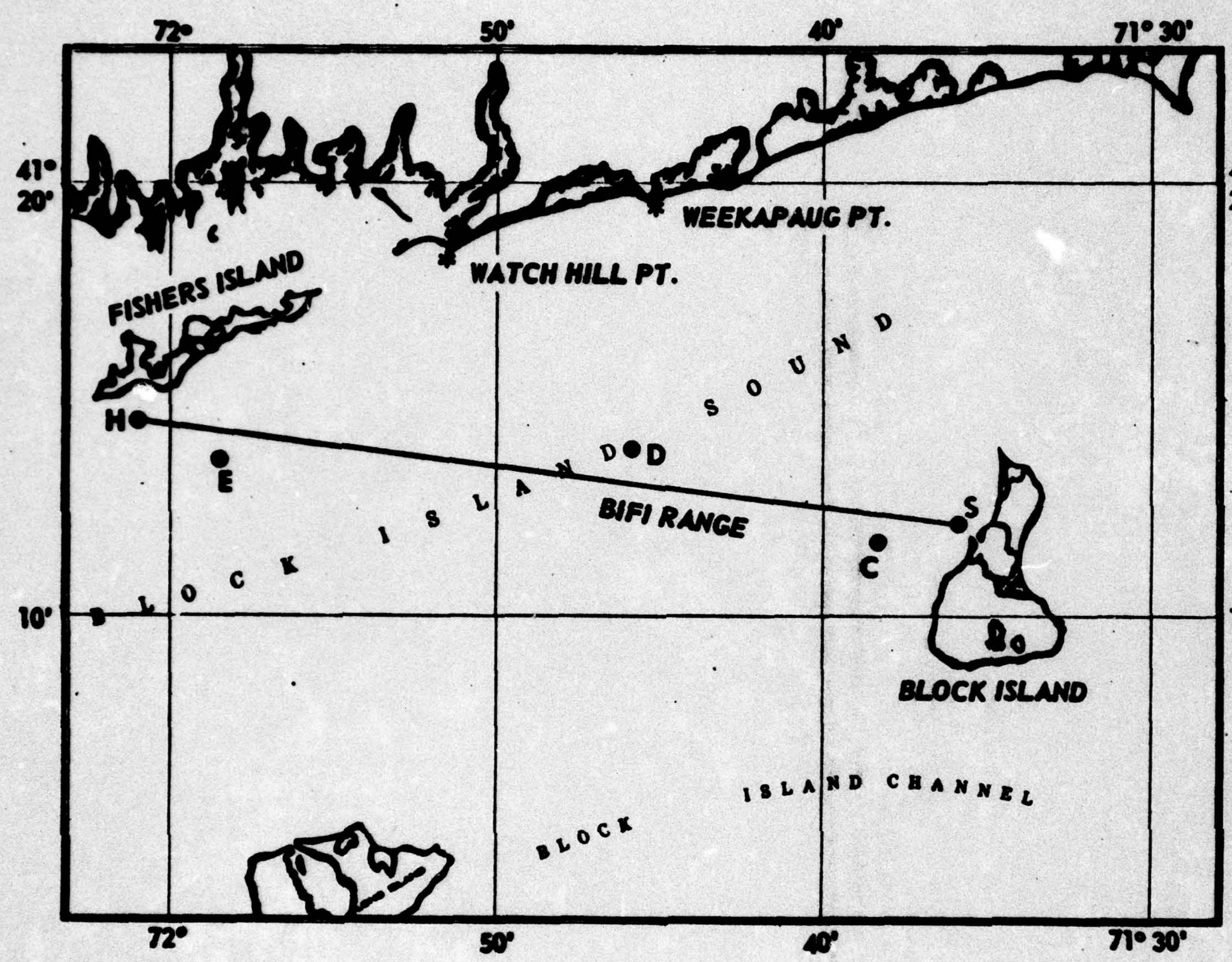

FIGURE 1

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Official Photograph

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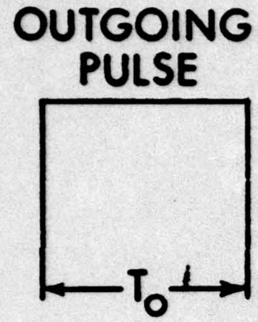
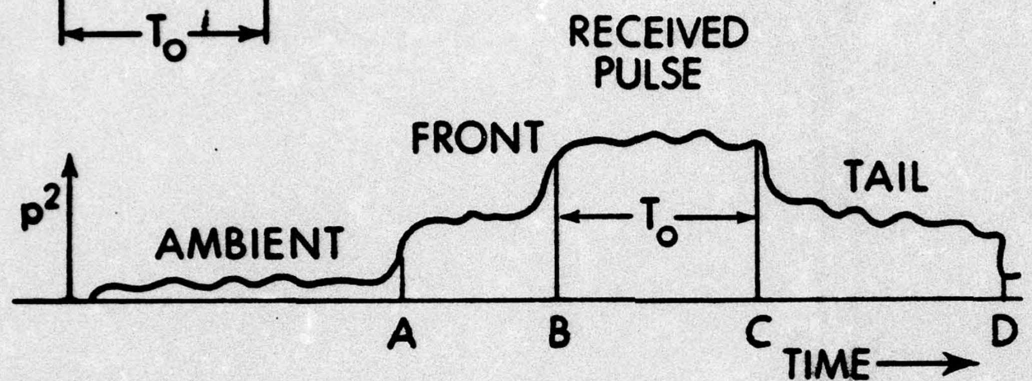
TIME SMEAR

OUTGOING PULSE AND RECEIVED SIGNAL





$$E_{amb} = \int_{x}^{T_o + x} p^2 dt \qquad \int_{A}^{A+T_o} p^2 dt > kE_{amb} \qquad \int_{D-T_o}^{D} p^2 dt > kE_{amb}$$

$$p_A^2 > \frac{kE_{amb}}{T_o} \qquad \int_{B}^{C} p^2 dt \text{ IS MAXIMUM} \qquad p_D^2 > \frac{kE_{amb}}{T_o}$$

$$\int_{A}^{B} p^2 dt > \frac{k(B-A)}{T_o} E_{amb} \qquad \int_{C}^{D} p^2 dt > \frac{k(D-C)}{T_o} E_{amb}$$

Figure 2

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Official Photograph

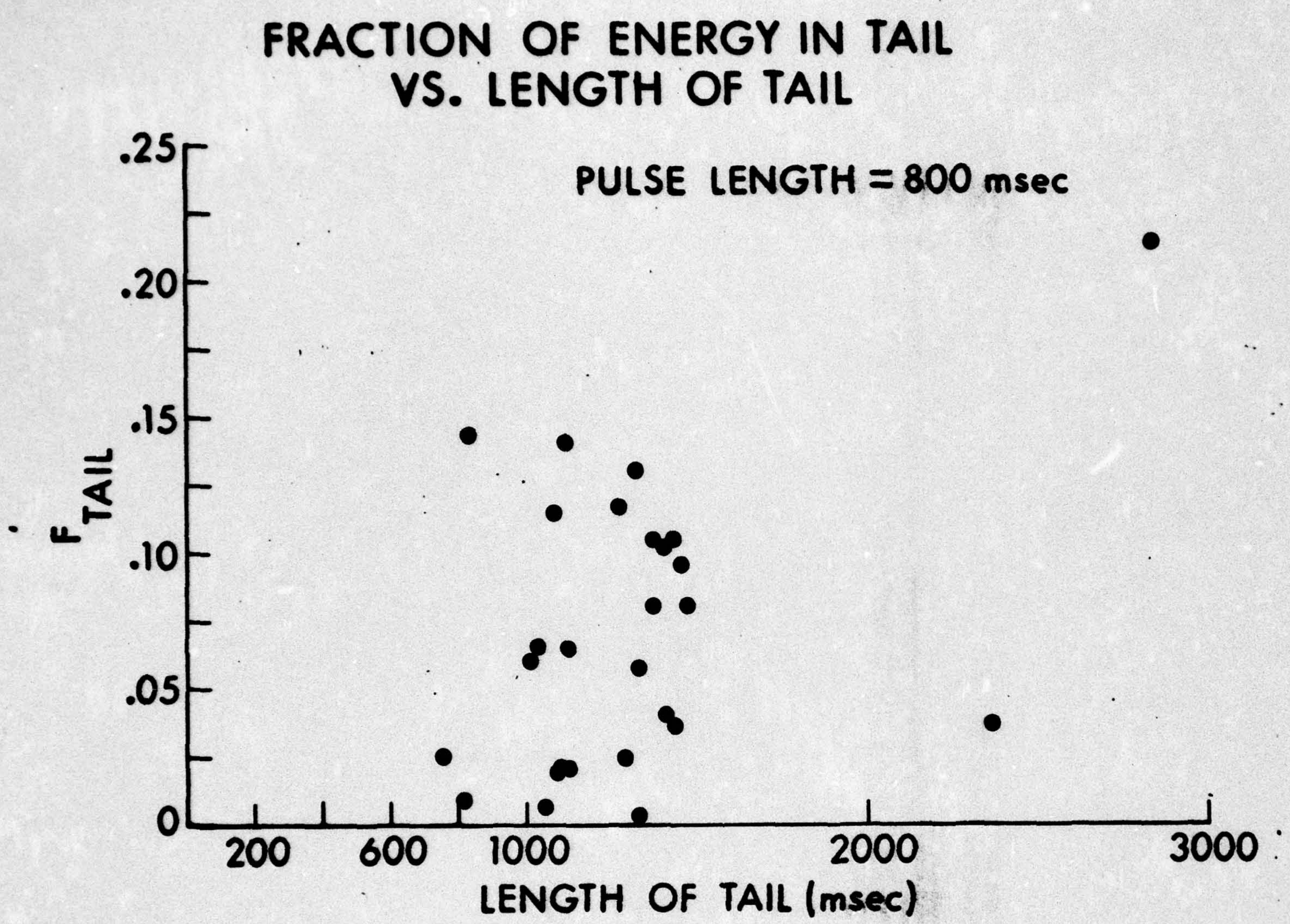

Figure 3

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FACTORS CONTRIBUTING TO ENERGY DISPERSION

FACTOR	VALUE		CONTRIBUTION (DB)	
	LOW SEA STATE	HIGH SEA STATE	LOW SEA STATE	HIGH SEA STATE
MEDIAN VALUE OF F(TAIL)	066	.084	4.5	5.2
MAXIMUM VALUE OF F(TAIL)	0.21	0.86	8.6	28.4
MAX/MIN RATIO OF RECEIVED PULSE	10.2	80.5	10.1	19.1
TOTAL			18.7	47.5

Figure 4

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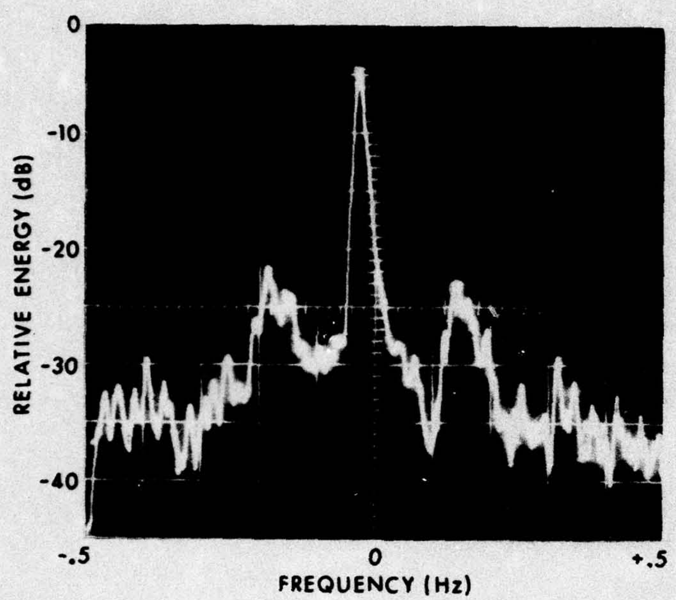

Fig. 5

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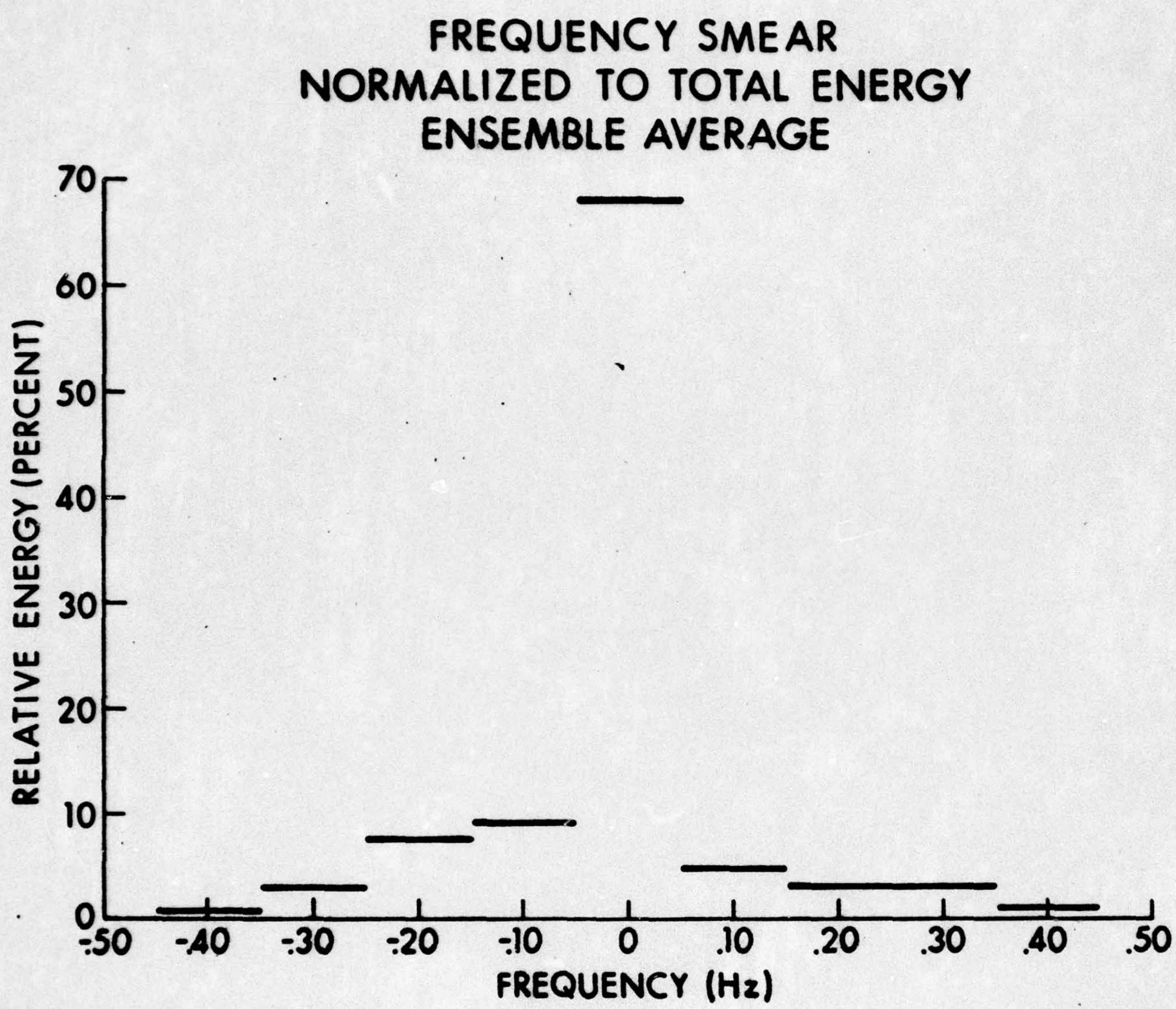

Figure 6

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ENERGY DISPERSION

SEA STATE	ENERGY (PERCENT)
0	80.8
1	76.6
2	75.0
3	70.9

WIND SPEED (KTS)	ENERGY (PERCENT)
0	80.1
5	77.3
10	81.3
15	68.6
20	68.2
25	65.3
30	70.2
35	65.1

Figure 7

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ENERGY DISPERSION DURING 48 HOUR INTERVAL

CONDITION	ENERGY (PERCENT)
SEA STATE 0	85.4
RAIN-WIND BUILDUP	67.6
SEA STATE 2 WIND 10-15 KTS	76.0
CALMING	67.2

Figure 8